INVERTEBRATE POPULATIONS IN THE NESTS OF A SCREECH OWL *(OTUS ASIO)* AND AN AMERICAN KESTREL *(FALCO SPARVERIUS)* IN CENTRAL NEW YORK[1]

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ABSTRACT: Screech owl *(Otus asio)* nest material from a tree hole in Syracuse, N.Y., contained 22,991 arthropods of 61 species. Arthropod density was 131/g dry weight of nest material. An American Kestrel (*Falco sparverius*) nest in a nest box in Jamesville, N.Y., yielded 26,553 invertebrates of 93 species. Arthropod density was 38/g dry weight of nest material. Lists of the species found and their populations are presented, and their trophic and symbiotic relationships are discussed. Bird parasite levels were extremely low. Litter fauna was dominant in the screech owl nest, while stored products fauna was dominant in the Kestrel nest.

Nests of birds harbor a wide variety of invertebrates,, including soil and litter, parasitic, predatory and coprophilic organisms. Numerous studies have demonstrated that birds' nests are reservoirs of domestic and stored products pests as well, containing populations of carpet beetles (Dermestidae), clothes moths (Tineidae), house dust mites (Pyroglyphidae), stored products mites (Glycyphagidae), and poultry mites (Macronyssidae) (Woodroffe and Southgate, 1951; Woodroffe, 1953, 1954; Baker *et al*., 1956). Nests of birds of prey (Falconiformes and Strigiformes) serve as a habitat for necrophilic arthropods as well as other nidicoles, since they contain carrion and regurgitated pellet remnants of their prey (Philips and Dindal, 1977).

The check-lists of Hicks (1959, 1962, 1971) serve as excellent guides to the literature on insects in birds nests, and they demonstrate how poorly raptor nest fauna is known. Prior to this study, only six species of invertebrates were known from eastern screech owl (*Otus asio* (L.)) nests (Baker, 1904, Bequaert, 1955, Gehlbach and Baldridge, 1987; Linsley, 1944; Robinson, 1941; Vaurie 1955) and only eight species were known from American kestrel (*Falco sparverius* L.) nests (Balgooyen, 1976, Bequaert, 1955; Capelle and Whitworth, 1973; Hill and Work, 1947; Roest, 1957; Williams, 1947). The objective of this study was to investigate the invertebrate community of a screech owl and a kestrel nest, and to determine the levels of parasites, pest, and other species infestation in them.

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METHODS

Eastern screech owls occur in mixed woodlands east of the Rocky Mountains, feeding on small vertebrates and invertebrates and roosting and nesting in hardwood tree hollows or occasionally in nest boxes (Hekstra, 1973; Karalus and Eckert, 1974). In 1975, screech owls were observed nesting and roosting in a tree hole 9m high in a white oak (*Quercus alba* L.) in Oakwood Cemetery, Syracuse, New York. On 12 March 1976, a 175 g dry wt. sample of nest material was collected from the tree hole. At this time the hole was being used by the owls, but egg-laying had not yet taken place. Most of the sample material was placed in modified Tullgren funnels (Murphy, 1962) for extraction of microarthropods, and weighed when dry. The rest was placed in culture dishes so that nidicolous insect larvae could be raised to adults for identification. On 16 June 1976, after nesting was over, a second small sample of nest material was collected and used for invertebrate extraction. Although the March sample removed most of the litter from the tree hole, it did not ruin the hole as a nest site, since the owls nested there in 1976 and 1977 as they had several years previously.

American kestrels inhabit open country in North and South America, like the screech owl feeding on small vertebrates and invertebrates and nesting in tree holes or nest boxes (Brown and Amadon, 1968). On 24 June 1976, the day after the nestlings fledged, we collected an American kestrel nest (705 g dry wt.) in a nest box 5m high in a dead tree in Jamesville, New York. The nest material was processed in the same way as the screech owl nest.

RESULTS

The March screech owl nest sample included as much of the nest debris as could be obtained through the tree hole. The material consisted mainly of bits of oak leaves and small twigs. Small amounts of grass, woodchips, dirt, eggshell, excreta, feathers and pellet material (chitin, hair and bones) were also present. Prey remains included a skull and jaw of *Microtus pennsylvanicus* (Ord.). Funnel extraction yielded 22,991 microarthropods of 61 species (Table 1). Fifteen species of insects were found, but 99% of the individuals were mites. Arthropod density was 131/g dry wt. of nest; individual species and their populations are given in Table 2.

The June screech owl postnesting sample containing basal material from the nest hole was not analyzed in detail. A survey of the June nest fauna revealed that almost all of the species present were also present in the March sample. Relative populations were quite different, but that is probably more the result of the site disturbance in March - removing so much of the litter in the hole - than the result of changes associated with the nesting cycle. Two species were present in June that were not observed in March - *Dendrophaonia scabra* G. -T. (Diptera: Muscidae) and *Trox variolatus* Mels. (Coleoptera: Trogidae).

The American kestrel nest was composed mainly of sawdust with bits of sticks, leaves, moss, grass, wood, excreta, chitinous prey remains, pellets of hair, bone and chitin and several prey feet. Identifiable prey remains included two skulls of *Microtus pennsylvanicus* (Ord.) and many fragments of the carabid beetle *Calosoma frigidum* Kirby. One avian skull was found, probably that of a sparrow. The nest sample contained 26,553 individuals of 93 species (Table 1). Thirty-one species of insects were found, but 90% of the individuals were mites. Arthropod density was 38/g dry wt.; individual species and their populations are given in Table 3.

BIOLOGICAL ANNOTATIONS ON COLLECTED TAXA

Screech Owl Nest Fauna

Ramusella clavipectinata (Mich.), the numerically dominant species in this nest community, is a widespread oribatid mite fungivore which Mahunka (1986) found to be very abundant in Hungary. Conditions in the tree-hole full of highly decomposed leaf litter were near optimal for this mite, judging by its tremendous population. The nest oribatids are part of the humus fauna involved in the decomposition of the nest material.

The astigmatic mites found included nest humus and animal remains fauna, with several new genera and species (Fain and Philips, 1977a, 1977b, 1978a, 1979, 1981). *Fuscarus* was previously known only from rodent nests, and nothing was known of its food habits (Krantz, 1978). We observed fungal spores as gut contents of all stages of *Fusacarus tenuipes* (Fain and Philips), and the fungus species was the same as that eaten by *Oppia* and *Acotyledon*.

Acotyledon paradoxa Ouds. was previously known only from phoretic deutonymphs and a protonymph. The discovery of all stages of this species has enabled taxonomists to clarify the systematic position of the genus. This species has been found on a bat and in granaries in the Soviet Union, and in mouse nests in the U.S.A. (Fain and Philips, 1978c).

Histiogaster robustus Wdrg. is known from trees (Woodring, 1966b). Other species in the genus have been found associated with bark beetles.

The histiostomatids collected were represented mainly by the entomophilic nonfeeding hypopus stage. Development of this stage from protonymphs may have been triggered by the extraction process. Histiostomatids were not common in the nest leaf litter, but were abundant in the basal hole debris of the postnesting sample. One species of *Myianoetus* is known to be phoretic on *Muscina stabulans* (Fall.) (Hughes and Jackson, 1958). In the June sample we observed 20 *Histiostoma pauciputeolum* Fain and Philips hypopodes on the head, legs, and abdomen of a *Trox variolatus* Mels. beetle larva. An adult *T. variolatus* carried 53 of these hypopodes, almost all on the legs. In the March sample, one histerid beetle adult of *Dendrophilus xavieri* Mars. bore 20 of these hypopodes, mainly on the elytra and abdomen. Feeding stages of histiostomatid mites generally strain microorganisms from wet substrates (Krantz, 1978).

Besides *Histiostoma* hypopodes, the adult trogid beetle carried 137 hypopodes of *Euglycyphagus*, on the pronotum, metasternum, elytra and abdomen. *Euglycyphagus* is fungivorous to some extent and, like the histiostomatids, was most abundant in the basal debris. Histiostomatid and glycyphagoid mites have not previously been found on trogid beetles, although Fain and Philips (1978b) have described a new species of winterschmidtiid mite from Australian trogid beetles.

Sapracarus tuberculatus Fain and Philips, known only from this nest, may be a strict nidicole or general tree-hole dweller. Its entomophilic hypopus indicates a phoretic relationship with some insect. This mite is presumably detritivore, but no gut contents were visible in the specimens examined.

Echimyopus is a mite genus known as deutonymphs from hair follicles and skin galls of Central American rodents and marsupials (Fain, 1969; Fain *et al.*, 1973; Fain and Lukoschus, 1976). One previous record of the genus exists for North America, from squirrel hosts (Whitaker *et al.* 1975). Adults and nymphs of this genus had not previously been found (Fain and Philips, 1981).

Orycteroxenus hypopodes occur on mammal hair, and the occurrence of one hypopus of *O. soricis* (Ouds.) can be correlated with our finding of prey remains of one of its hosts, *Microtus pennsylvanicus* (Fain, 1969; Fain and Whitaker, 1973). *Neoxenoryctes* hypopodes also are pilicolous, and the nymphs and adults are at least partly fungivorous.

The chigger *Miyatrombicula cynos* Ewing is known from raccoons and squirrels (Ewing, 1937; Whitaker *et al.*, 1975). All stages of this mite were found in the nest, and over half of the larvae were engorged. Since many chiggers show little host specificity, it is possible tht the screech owl could be an acceptable host for this species, but more likely the hole had been used by squirrels previously, and the owls had only recently taken possession again for nesting.

Tarsocheylus paradoxus Berl. is known from tree-holes and rotting bark (Atyeo and Baker, 1964). Pyemotids, scutacarids, tarsonemids, and tydeids are all soil and litter groups, which pierce and suck fluids from fungi and/or nematodes (Moore *et al.*, 1988). *Proctotydaeus* is an insect associate (Andre, 1980) and may have reached the nest on moths, since Treat (1961) found one species phoretic on noctuid moths. Cheyletids are common nest predators, and Woodroffe (1953) observed that the acarid mite *Tyrophagus* is preferred prey for *Cheyletus eruditus* (Schr.); perhaps in this nest it was mainly preying on *Acotyledon*, the most abundant acarid mite present.

The mesostigmatic mites found included gamasine parasites of birds and mammals, gamasine predators, and uropodine fungivores. Species of *Laelaps*, *Haemogamasus*, *Hyperlaelaps*, and *Androlaelaps fahrenholzi* (Berl.) are small mammal parasites with many hosts (Whitaker and Wilson, 1974). *Androlaelaps casalis* (Berl.) has been described as a mammal and bird ectoparasite common in bird nests (Wilson and Bull, 1977., Rosen *et al.* 1985), but McKinley (1963) concluded that this species did not pierce mammal or avian skin, and actually fed on other mites, such as acaridids, and their eggs.

Hypoaspis, Blattisocius, and *Proctolaelaps* are common nest predators. The size difference in the three *Dendrolaelaps* species suggests possible differences in prey size classes. Many ameroseiids feed on fungi or pollen, but can also be predators (Krantz, 1978). They occur in litter as well as mammal nests. Among the uropodines, *Metagynella parvula* Camin is known only from tree-holes (Camin, 1953). Its phoretic relationships, if any, are unknown. One deutonymph of *Trichouropoda martini* Hirschmann was phoretic on the histerid beetle *Dendrophilus xavieri* Marseul. *Trichouropoda martini* is known from a red squirrel (*Tamiasciurus*) nest (W. Hirschmann, pers. comm.). *Uroseius* deutonymphs have been found in passerine nests phoretic on trogid beetles (Sixl, 1971).

The pseudoscorpion *Acuminochernes crassopalpus* (Hoff) is a predator that has been previously recorded from treeholes (Park and Auerback, 1954) and mammal nests (Muchmore, pers. comm.). Chernetid pseudoscorpions posses several adaptations for colonizing nests and treeholes, including phoresy and the ability to store sperm for prolonged periods (Jones, 1975).

Most of the fly larvae are known scavengers on animal remains, but scenopinid larvae prey mainly on tineid moth larvae. The cecidomyid larvae were probably saprovores associated with the decaying nest plant matter.

Beetles associated with treeholes rather than birds' nests included the curculionid adult and the melandryid, tenebrionid and staphylinid larvae (Borror *et al.*, 1981). *Xylodromus* is a new staphylinid record for New York (Moore and Legner, 1975). The histerid beetles were the largest predators in the nest.

Only a few fleas were found, and both species are mammal parasites.

Orchopeas howardi (Baker) is most commonly found on tree squirrels and *O. leucopus* (Baker) prefers *Peromyscus* (Main, 1970). *Ixodes marxi* Banks, the single tick found, is also a tree squirrel parasite (Bequaert, 1945).

The single psocopteran appears to be an accident. It may have been windborne or reached the nest on a bird or mammal, as phoresy occasionally occurs in psocopterans (Mockford, 1967). The only wasp found, *Synergus*, was extracted from a gall on one of the nest leaves.

The ectoparasites found included the squirrel tick, the squirrel flea, a squirrel chigger, three parasitic mesostigmatic mite species known from squirrels, and an astigmatic mite genus known from squirrels. Also, the nest contained many mammal nest associates such as *Fusacarus* and *Neoxenoryctes*. Oakwood Cemetry abounds in gray squirrels (*Sciurus carolinensis* Gmelin), and it seems inevitable that this tree-hole would be occasionally visited by squirrels when not used by the owls. In 1977, the owls again nested in this hole, as they had for several previous years, but in 1978 squirrels took over the hole and the owls did not nest there.

Squirrel use of the hole explains the many squirrel parasites found. We believe that the hosts of *Echimyopus orphanus* Fain and Philips and *Neoxenoryctes* is the gray squirrel, and that these other genera like *Fusacarus* will also be found in gray squirrel nests.

This nest community was characterized by very high species richness and very low equitability. The variety of food sources in the tree-hole nest provide a habitat for many species which colonize the hole deliberately or accidentally, and the protected microenvironment seems to provide nearly optimal conditions for some species.

American Kestrel Nest Fauna

The kestrel nest invertebrate community was very different from the screech owl nest community. Of 93 species in the kestrel nest, only 12 were also present in the screech owl nest. These species - 9 mites, a histerid beetle, a sphaerocerid fly, and a psocopteran - included no avian parasites and were small components of both nests, comprising only 8% of the individuals in the screech owl nest, and 4% of those in the kestrel nest. Four of the mites are parasitic or phoretic on rodents. Three additional species may be common to both nests. Lack of adults of the scenopinid fly, the tineid moth in the kestrel nest, and the uroseiid mite in the screech owl nest, prevented complete identification.

Diversity in the kestrel nest was lower than in the screech owl nest. Although species richness was higher than that of the screech owl nest, equitability was lower, as was arthropod density. In this nest, a new species of *Lardoglyphus*, a genus known from dried fish, butchers' offal, and hides (Hughes, 1976) was highly numerically dominant. This species was fungivorous to some extent, and the hypopodes were phoretic on *Dermestes pulcher* LeConte (Philips and Norton, 1978). It seems to have some degree of host specificity. A nest box in a tree 18m from this kestrel nest was examined and preliminary inspection has revealed neither *Lardoglyphus falconidus* Philips and Norton nor its dermestid host species. Another genus of dermestid was present, as were the species of *Lepidoglyphus* and *Cheyletus* which occurred in this kestrel nest.

Other genera of acarid mites in this nest with entomophilic hypopodes were *Histiogaster*, *Michaelopus*, *Sancassania*, and *Schwiebea*. *Michaelopus corticalis* (Michael) has been found under dead tree bark and in nests of several avian orders (Fain, 1982), and is probably saprophagous like *Sancassania* and *Schwiebea*. *Schwiebea terrana* Jacot was originally collected from pine litter and inhabits dead wood (Woodring, 1966a).

Histiostomatid mite hypopodes were found phoretic on *Trox seaber* (L.) in this nest, as they were on the other species of trogid beetle in the screech owl nest. Thirteen hypopodes were found under the wings of the trogid, in crevices at the border of the thoracic and abdominal regions of the body. Twelve hypopodes were *Histiostoma* species number three, and one was *Hexanoetus conoidalis* Fain and Philips. *Hexanoetus conoidalis* was present in adult and immature stages in the screech owl nest. *Histiostoma* species number 3 is identical to the *Histiostoma* species B found by Philips *et al.* (1983) under the elytra of four specimens of *Trox aequalis* Say in a saw-whet owl (*Aegolius acadicus* (Gmelin)) nest in Connecticut.

Two species of feather mites were found in the nest. The specimens of *Dubininia* in the pellet sample may have been regurgitated with a pellet or may have dropped off from a kestrel in the nest, as this genus is a parasite of the Falconiformes as well as other birds. *Analges* probably was derived from prey.

Lepidoglyphus fustifer (Ouds.) is a European stored products species. It has not previously been recorded from North America (Hughes, 1976) and the hypopus stage was not previously known from this species. We have observed fungal spores in the gut of many of our specimens.

As with the screech owl nest, a few *Orycteroxenus* hypopodes were found, as well as evidence of predation on *Microtus*. *Glycyphagus hypudaei* (Koch) hypopodes are phoretic on *Microtus* and many other small mammals. *Myocoptes japonensis* Radford is a parasite whose type host is *Microtus pennsylvanicus* and type locality is Ithaca, N.Y. (Fain and Hyland, 1970). *Dermacarus sciurinus* (Koch), another mammal associate, is known from a *Peromyscus* nest (Fain and Whitaker, 1973).

Tytodectes cerchneis Fain was previously known only from one badly damaged specimen found on *Falco tinnunculus* L. in Rwanda, Africa

(Fain 1967). The hypoderid mites are a poorly known group, and the life cycle of very few species is completely known. The hypopus is a subcutaneous parasite of birds, and the other immature stages are not active. The adults are very short-lived and nonfeeding nidicoles (Fain and Bafort, 1967).

The finding of *Tytodectes* represents a new U.S. record. Both *Falco sparverius* and *F. tinnunculus* also have a nasal mite species in common, and it would be interesting to survey falcon nasal, subcutaneous, and other mites and compare that data with concepts in falcon taxonomic relationships.

Nanacarus is a new New York record. This genus contains a number of fungivorous species which inhabit polypore fungi (O'Connor, 1984).

Among the prostigmatic mites present were two mammal parasites -a nymphal myobiid mite and a *Demodex*, as well as tarsonemid and tydeid soil and litter species. There was no mammal carrion in the nest, so we believe the parasites either came off prey in the nest before the prey was eaten, or survived the bird's digestive tract and came out in regurgitated pellet or fecal material.

Cheyletus trouessarti Oudemans was the most abundant predatory mite in the nest. Cheyletids are often associated with infestations of acarid mites (Baker, 1949) and we believe this species was probably feeding mainly on the abundant *Lardoglyphus* in this nest. Anystids are very mobile predatory mites which often feed on phytophagous insects and mites. The one larvae found may have wandered into the nest box from the tree the box was on, as these mites are long-legged rapid movers (Krantz, 1978).

As with the screech owl nest, the mesostigmatic mites included gamasine mammal parasites, gamasine predators, and uropodine fungivores, but there were no gamasine avian parasites. *Poecilochirus necrophori* Vitzth. is known to be phoretic on the silphid beetle *Nicrophorus* (Chmielewski, 1977) and the presence of four on *Nicrophorus pustulatus* Hers. explains how this mite reached the nest. This mite probably preys on nest fly larvae. *Macrocheles muscaedomesticae*, another immature dipteran predator (Peck and Anderson, 1969), is known to be phoretic on muscid flies (Evans and Browning, 1956; Chmielewski, 1977). *Copriphis* is a predatory gamasine which is phoretic on scarabaeid dung beetles. Two females were found under the wings of *Trox scaber* near the thorax/abdomen border. This species is identical to the species of "*Eviphis*" found by Philips *et al.* (1983) under the elytra of *Trox aequalis* in a saw-whet owl nest in Connecticut. *Copriphis* has been considered by some taxonomists to be a synonym of *Eviphis*, but we agree with those regarding it as a distinct genus. *Ameroseius apodius* Karg was discovered by Karg (1971) in compost in Germany, and has not previously been found in the

U.S.A. *Trichouropoda falconis* was recently described as a new species from this nest by Hirschmann and Wisniewski (1988). *Trichouropoda* species number one was found as a phoretic deutonymph attached by anal stalk to tibia IV of an adult histerid beetle, *Carcinops pumilio* Erichson.

Very few oribatid mites were present in this nest, which was dominated by animal remains fauna. Other humus fauna species were equally scarce - one collembolan, one enchytraeid, two earthworms, and a few Psocoptera. To our knowledge, earthworms have only been previously recorded from nests of one bird - the rook (*Corvus frugilegus* L.) in Britain (Coombs, 1960). Earthworm presence in a kestrel nest may be due to prey escape, since kestrels prey on earthworms (Balgooyen, 1976). Clubionid spiders hunt both on the ground and in foliage (Kaston, 1972), and probably entered the nest while foraging on the tree.

Histerids again were the largest predators in the nest. While the food of many species of staphylinids is not known, Koskel and Hanski (1977) classify all aleocharines and staphylinines (like *Philonthus*) as carnivores. *Nicrophorus* may prey on maggots, as well as eating carrion (Steele, 1927). Lathridiid and tenebrionid fungivores are very common in birds' nests and *Tenebrio molitor* L. is a stored products pest (Woodroffe and Southgate, 1951).

Calosoma frigidum Kirby is a new prey record for the American kestrel (Philips, 1977). This carabid beetle was known to be preyed upon by only one bird - the ruffed grouse (*Bonasa umbellus* (L.)) (Larochelle, 1975), but this demonstrates the paucity of knowledge on avian insect predation.

Allen (1973) has noted that this carabid preys upon several important insect pests, and its habit of tree foraging may make this species more susceptible to kestrel predation than cryptozoic ground carabids, particularly when, as Allen observed, large numbers of this carabid beetle occur during major infestations of forest insect pests.

The trogid and dermestid beetles eat hair and feathers in animal remains like carrion and raptor pellets. *Trox scaber* (L.) is known from mammal nests and nests of several other birds, including the screech owl (Vaurie, 1955). Unidentified species of *Dermestes* were recorded from kestrel nests by Balgooyen (1976). *Nicrophorus* feeds on fresher carrion than *Dermestes*.

Scavenging dipteran larvae occurred as in the screech owl nest, but in much greater numbers and in greater variety, with muscid and scatopsid flies present. Two families of avian parasitic flies inhabited this nest. The biting midges (ceratopogonids) suck blood, but the food habits of the nidicolous milichiid *Carnus hemapterus* Nit. have been a subject of debate. Bequaert (1942) has quoted the observations of earlier workers who discovered that it fed on blood and that it fed on skin and feather secretions. Borror *et al.* (1981) consider it to be blood-sucking. Lloyd and Philip (1966) agreed with Bequaert that the mouthparts are not adapted for piercing host skin.

One parasitoid cynipid wasp inhabited this nest, but the hosts of many species of *Pseudeucoila* are not known (Muesebeck *et al.*, 1951). The mymarid wasp is a parasite of insect eggs (Borror *et al.* 1981). Many braconid wasps are parasites of lepidopteran larvae (Borror *et al.* 1981). *Lasius* ants nest in rotting logs and stones and cultivate aphids (Arnett, 1985). The three nest anoplurans can be attributed to the birds' mammalian prey. The two flea larvae could not be specifically identified.

DISCUSSION

These raptor nest data present a considerably different picture of the nest community than previous studies. Although Nordberg (1936) found oribatid mites of many species in his European raptor nests, very few species occurred in our nests. Nordberg found mainly feather mites among the astigmatic mites in his nests, but our nests contained a wide variety of astigmatic mites. The prostigmatic and mesostigmatic mite components of raptor nests are also much more diverse than were previously realized. In particular, no mammalian-associated mites had been reported from raptor nests. Our expectations that they would be found still did not encompass the actual extent of the mammal nest and parasite fauna in raptor nests.

The mite family Pyroglyphidae is very common in birds' nests (Woodroffe, 1953; Krantz, 1978), but has never been previously found in raptor nests, and only three specimens were found in our nest samples. Its scarcity in the kestrel nest is even more surprising considering its abundance in a tree swallow (*Iridoprocne bicolor* (Vieillot)) we examined which was in a nestbox only 200 m away. More samples are needed to confirm this apparent preference for nonraptor nests - perhaps the raptor nest moisture and carrion create an unattractive environment. Woodroffe (1953) noted that these mites are tolerant of low humidities and occur in very dry nests. Some nest pyroglyphids also occur in house dust and cause house dust allergy (Krantz, 1978).

Referring to mites in bird nestbox debris, Herman (1936) stated that "an estimate of billions in each nest seems conservative". He correctly judged the importance of the mites, if not their actual density. Nevertheless, the densities of arthropods in the screech owl and kestrel nests are high. Park *et al.* (1950) studied the tree-hole fauna of elm, sugar maple, and beech trees, and arthropod densities ranged from 4.4-5.5/g. Ryder and Freitag (1974) examined ring-billed gull (*Larus delawarensis* Ord) nests of weights similar to the screech owl and kestrel nests, and densities averaged 1.5-1.7 arthropods/g.

The oribatid mite density in the screech owl nest appears to be unmatched in any other reported nest. Gembestky and Andrechikova (1969) examined 32 nests of 7 passeriform species and collected only 98 oribatid specimens. Bukva *et al.* (1976) found 979 oribatids in 278 small mammal nests, and Kramarova and Mrciak (1971) collected 13,364 from 303 small mammal nests.

Kramarova and Mrciak studied the invertebrate groups in small mammal nests as we did with the raptor nest groups. Some additional numbers from their 303 nests provide a useful comparison: 20,556 astigmatic mites; 110,575 mesostigmatic mites; 679 prostigmatic mites; 71 pseudoscorpions; 22,213 Collembola. Vysotskaya and Nosek (1974) studied 43,796 Collembola from 464 small mammal nests.

The dominance of gamasine mites, especially parasites, in small mammal nests has also been shown by Drummond (1957) and Allred and Roscoe (1957). Judging from our data, astigmatic or oribatid mites can be dominant in raptor nests, and although a variety of mesostigmatic mites occur, they are not present in tremendous numbers.

Park and Auerbach (1954) found that collembolans made up 27% of the tree-hole fauna they studied. Considering their abundance in small mammal nests and treeholes, the scarcity of collembolans in the raptor nests examined is surprising. Further study is needed to determine the frequency of Collembola in many raptor nests.

Woodroffe and Southgate (1951) studied passerine nests and observed a succession of invertebrates. Avian ectoparasites dominated during initial nest construction and occupation. After birds left the nest, scavenging invertebrates were dominant as feather debris and excreta decomposed. The final stage of decomposition of the nest material was dominated by humus fauna. If the nest was used as a winter roost and reused the next year, the nest acted as a refugium and the scavenging fauna persisted. Open, exposed nests decomposed faster and the scavenging stage was reduced or absent. Differences in the fauna of nests of different bird species were correlated with differences in the composition of the nests.

This pattern is not consistent for all birds' nests. Freitag and Ryder (1973) found almost no ectoparasites in their ring-billed gull nests. Saprophagous mite populations peaked after gull egg-laying, while predatory mite populations peaked at or after egg-hatching (Freitag *et al.*, 1974).

Trophic category estimates of the raptor nest fauna are given in Table 4. There is no evidence that the raptor nests followed Woodroffe's scheme, as very few avian ectoparasites were found. However, the scavenging animal remains fauna was dominant in our samples taken immediately after falconiform nesting. The effects of screech owl nesting upon the nest humus fauna were not observed because of our disturbance of the site. It is possible that this fauna could have remained dominant throughout the entire nesting period, but an increase in the animal remains fauna would still be expected as that food source became more abundant.

Hagvar (1975) described coleopteran succession in raptor nests. Nests used every year grow larger, older material decomposes, and the number of niches increases. Old nests in use have the largest species richness, and large old nests can remain humid in the center even during droughts.

Succession in raptor nests is complicated by the many variables in nest location and use. Nests may be used in other seasons and years by other roosting species, and raptors may share their nests with a variety of other vertebrates (Wilson, 1925; Sumner, 1933; Zarn, 1974).

Detailed investigations of raptor nest fauna are needed to elucidate the intricate interrelationships in this microcommunity. Many raptors are marginal or endangered species, and we need to know what, if any, invertebrates may be a source of mortality and how frequently this occurs. When nest trophic interactions are well known, biological control measures against undesirable invertebrates may be possible.

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Table 1. Invertebrates in the nests of a screech owl and an American kestrel.

Group	Screech Owl species	Screech Owl individuals	% of total individuals	American Kestrel species	American Kestrel individuals	% of total individuals
Arachnida						
Acari						
Acaridida	12	5,720	24.88	20	19,692	74.16
Actinedida	11	4,168	18.13	8	4,015	15.12
Gamasida	17	625	2.71	15	238	.90
Ixodida	1	1	.004			
Oribatida	4	12,214	53.13	15	49	.18
Araneida				1	1	.005
Pseudoscorpionida	1	119	.52			
Insecta						
Anoplura				1	3	.01
Coleoptera	5	27	.12	13	485	1.83
Collembola				1	1	.005
Diptera	4	93	.40	9	2,007	7.56
Hymenoptera	1	1	.003	4	7	.03
Lepidoptera	2	18	.08	1	2	.01
Psocoptera	1	1	.003	1	48	.18
Siphonaptera	2	4	.02	1	2	.01
Oligochaeta				3	3	.01
Total	61	22,991		93	26,553	

Table 2. Arthropod species populations in a screech owl nest.

Class Arachnida		
Order Acarina		
Suborder	Acaridida	
Family	Acaridae	
	Acotyledon paradoxa Oudemans	3,746
	Histiogaster robustus Woodring	9
Family	Euglycyphagidae	
	Euglycyphagus intercalatus Fain and Philips	150
Family	Glycyphagidae	
	Echimyopus orphanus Fain and Philips	12
	Fusacarus tenuipes Fain and Philips	614
	Neoxenoryctes reticulatus Fain and Philips	1,053
	Orycteroxenus soricis soricis (Oudemans)	1
Family	Hemisarcoptidae	
	Sapracarus tuberculatus Fain and Philips	59

Family	Histiostomatidae	
	Comyianoetus denticulatus Fain and Philips	34
	Histiostoma pauciputeolum Fain and Philips	30
	Miyanoetus micromaculatus Fain and Philips	2
	Hexanoetus conoidalis Fain and Philips	10
Suborder	Actinedida	
Family	Cheyletidae	
	Cheyletus eruditus (Schrank)	166
Family	Pyemotidae	
	Bakerdania sp. 1	252
	Bakerdania sp. 2	28
	Brennandania sp.	20
Family	Scutacaridae	
	Imparipes sp.	13
Family	Tarsocheylidae	
	Tarsocheylus paradoxus Berlese	4
Family	Trombiculidae	
	Miyatrombicula cynos Ewing	869
Family	Tarsonemidae	
	Tarsonemus sp.	1,287
Family	Tydeidae	
	Proctotydaeus sp.	17
	Microtydeus sp.	4
	Tydeus sp. 1	1,508
Suborder	Gamasida	
Family	Ameroseiidae	
	Kleemannia sn. sp.	45
Family	Ascidae	
	Blattisocius dentriticus (Berlese)	15
	Proctolaelaps pomorum (Oudemans)	33
Family	Digamasellidae	
	Dendrolaelaps sp. nr. *marylandae* (Hurlbutt)	11
	Dendrolaelaps sp. nr. *pini* Hirschmann	24
	Dendrolaelaps sp. nr. *presepum* (Berlese)	13
Family	Laelapidae	
	Androlaelaps casalis casalis Berlese	8
	Androlaelaps fahrenholzi (Berlese)	3
	Haemogamasus reidi Ewing	2
	Hyperlaelaps microti (Ewing)	1
	Hypoaspis lubrica Voigts and Oudemans	109
	Laelaps alaskensis Grant	2
Family	Metagynuridae	
	Metagynella parvula Camin	2
Family	Polyaspinidae	
	Uroseius sp.	26
Family	Trematuridae	
	Trichouropoda martini Hirschmann	318
	species 1	12
	species 2	1
Suborder	Ixodida	
Family	Ixodidae	
	Ixodes marxi Banks	1

Suborder Oribatida		
Family Damaeidae		
	Epidameus canadensis (Banks)	1
Family Oppiidae		
	Ramusella clavipectinata (Michael)	12,056
Family Oribatulidae		
	Scheloribates sp.	153
Family Parakalummidae		
	Protokalumma n. sp.	4
Order Pseudoscorpionida		
Family Chernetidae		
	Acuminochernes crassopalpus (Hoff)	119
Class Insecta		
Order Coleoptera		
Family Curculionidae		
	Phloeophagus variolatus Drury	1
Family Histeridae		
	Dendrophilus xavieri Marseul	11
Family Melandryidae		
	Scraptinae sp.	8
Family Staphylinidae		
	Xylodromus sp.	4
Family Tenebrionidae		
	Neatus tenebrioides (Palisot)	3
Order Diptera		
Family Cecidomyiidae		
	Lestodiplosis sp.	19
Family Milichiidae		
	Leptometopa sp.	34
Family Scenopinidae		
	Scenopinus sp.	1
Family Sphaeroceridae		
	Leptocera (*Coproica*) n. sp.	39
Order Hymenoptera		
Family Cynipidae		
	Synergus sp.	1
Order Lepidoptera		
Family Noctuidae		
	Epizeuxis americalis (Guenee)	2
Family Tineidae		
	Tinea sp.	16
Order Psocoptera		
Family Liposcelidae		
	Liposcelis bostrychophilus Badonnel	1
Order Siphonaptera		
Family Ceratophyllidae		
	Orchopeas howardi howardi (Baker)	3
	Orchopeas leucopus (Baker)	1

Table 3. Invertebrate species populations in a American kestrel nest.

Phylum Annelida		
Class Chaetopoda		
Order Oligochaeta		
Family	Enchytraeidae	
	species 1	1
Family	Lumbricidae	
	Dendrobaena rubida (Savigny)	1
	Lumbricus sp.	1
Phylum Arthropoda		
Class Arachnida		
Order Acarina		
Suborder	Acaridida	
Family	Acaridae	
	Histiogaster carpio (Kramer)	1
	Lardoglyphus falconidus Fain and Philips	18,581
	Michaelopus corticalis (Michael)	1
	Sancassania sp.	1
	Schwiebea terrana Jacot	8
Family	Analgidae	
	Analges sp.	4
	Dubininia sp.	2
Family	Glycyphagidae	
	Dermacarus sciurinus (Koch)	1
	Glycyphagus hypudaei (Koch)	1
	Lepidoglyphus fustifer Oudemans	870
	Orycteroxenus soricis soricis (Oudemans)	2
Family	Hemisarcoptidae	
	Nanacarus n. sp.	3
Family	Histiostomatidae	
	Hexanoetus conoidalis Fain and Philips	1
	Histiostoma sp. 1	157
	Histiostoma sp. 2	13
	Histiostoma sp. 3	12
	Miyanoetus n. sp.	16
Family	Hypoderidae	
	Tytodectes cerechneis Fain	12
Family	Myocoptidae	
	Myocoptes japonensis Radford	1
Family	Pyroglyphidae	
	Dermatophagoides sp.	6
Suborder	Actinedida	
Family	Anystidae	
	species 1	1
Family	Cheyletidae	
	Cheyletus trouessarti Oudemans	1,859
Family	Demodicidae	
	Demodex n. sp.	1
Family	Myobiidae	
	species 1	1

Family	Tarsonemidae	
	Tarsonemus sp. 1	1,232
Family	Tydeidae	
	Coccotydaeolus sp.	1
	Tydeus sp. 1	703
	Tydeus sp. 2	217
Suborder	Gamasida	
Family	Ameroseiidae	
	Ameroseius apodius Karg	7
Family	Ascidae	
	Blattisocius tarsalis (Berlese)	2
	Proctolaelaps sp.	2
Family	Digamasellidae	
	Dendrolaelaps sp. nr. *presepum* (Berlese)	51
Family	Eviphididae	
	Copriphis sp	2
Family	Laelapidae	
	Androlaelaps fahrenholzi (Berlese)	3
	Hyperlaelaps microti (Ewing)	5
	Laelaps alaskensis Grant	9
Family	Macrochelidae	
	Macrocheles muscaedomesticae (Scopoli)	4
Family	Parasitidae	
	Poecilochirus necrophori Vitzthum	119
Family	Polyaspinidae	
	Uroseius lagenaeformis (Berlese)	6
Family	Trematuridae	
	Trichouropoda martini Hirschmann	15
	Trichouropoda falconis Hirschmann and Wisniewski	10
	Trchouropoda sp. 1	1
Suborder	Oribatida	
Family	Achipteriidae	
	Anachipteria sp.	2
Family	Cymbaeremaeidae	
	Scapheremaeus sp.	2
Family	Eremaeidae	
	Eremaeus sp.	1
Family	Oppiidae	
	Oppiella nova (Oudemans)	5
Family	Oribatellidae	
	Oribatella sp.	1
Family	Oribatulidae	
	Eporibatula sp.	1
	Oribatula tibialis (Nicolet)	1
	Phauloppa pilosa (Banks)	6
	Scheloribates sp. 1	9
	Zygoribatula frisae (Oudemans)	1
Family	Oripodidae	
	Oripoda sp.	2
Family	Parakalummidae	
	Protokalumma depressa (Banks)	3

Family Phthiracaridae		
	Phthiracarus setosellum Jacot	7
Family Tectocepheidae		
	Tectocepheus velatus (Michael)	6
Order Araneida		
Family Clubionidae		
species 1		1
Class Insecta		
Order Anoplura		
Family Hoplopleuridae		
species 1		3
Order Coleoptera		
Family Dermestidae		
	Dermestes pulcher LeConte	26
Family Histeridae		
	Carcinops pumilio Erichson	49
	Dendrophilus punctatus (Herbst)	2
	Dendrophilus xavieri Marseul	9
	Euspilotus sp.	4
	Gnathoncus sp.	5
	Margarinotus merdarius (Hoffman)	1
	larvae	278
Family Lathridiidae		
	Lthridius minutus (L.)	3
Family Silphidae		
	Nicrophorus pustulatus Herschel	1
Family Staphylinidae		
	Aleocharinae sp.	17
	Philonthus sp.	1
Family Tenebrionidae		
	Tenebrio molitor L.	92
Family Trogidae		
	Trox scaber (L.)	1
Order Collembola		
Family Entomobryidae		
	Willowsia buskii Lubbock	1
Order Diptera		
Family Ceratopogonidae		
	Culicoides sp. nr. *piliferus* Root and Hoffman	7
	Culicoides sp. nr. *travisis* Vargas	1
Family Milichiidae		
	Carnus hemapterus Nitzsch	38
	Leptometopa latipes (Meigen)	1,509
Family Muscidae		
	Fannia sp.	2
	Muscina stabulans Fallen	7
Family Scatopsidae		
	Coboldia fuscipes (Meigen)	4
Family Scenopinidae		
	Scenopinus sp.	5
Family Sphaeroceridae		
	Leptocera (*Coproica*) n. sp.	434

Order Hymenoptera		
Family	Braconidae	
	species 1	1
Family	Cynipidae	
	Pseudeucoila sp.	1
Family	Formicidae	
	Lasius alienus (Foerster)	1
Family	Mymaridae	
	species 1	4
Order Lepidoptera		
Family	Tineidae	
	species 1	2
Order Psocoptera		
Family	Liposcelidae	
	Liposcelis bostrychophilus Badonnel	48
Order Siphonaptera		
	species 1	2

Table 4. Trophic classification of raptor nest fauna.

Category	% individuals per nest Screech Owl	 American Kestrel
Animal remains saprovores	27.65	82.19
Nest material saprovores	60.01	8.35
Predators	8.47	9.11
Parasites of vertebrates	3.87	.33
Parasites of invertebrates	0	.02

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